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No. 552

WIND-TUNNEL TESTS OF WING FLAPS
SUITABLE FOR DIRECT CONTROL OF GLIDE-PATH ANGLE

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SUMMARY

Preliminary tests have been made in the N.A.C.A. 7- by 10-foot wind tunnel for the purpose of obtaining a flap arrangement suitable for direct and immediate control of the steepness of the glide path of an airplane, a use for which present flaps are not satisfactory. An attempt has been made to develop a flap giving a reasonably high maximum lift coefficient with relatively low deflection and maintaining this value of the maximum lift coefficient with a large increase of deflection, the increase in deflection being accompanied by a large increase in drag. An arrangement was found that gave a maximum lift coefficient of approximately 1.90 for all flap deflections between 25° and 80°, within which range the drag of the wing increased regularly to a large value.

INTRODUCTION

The usual high-lift flaps increase the drag in larger proportion than they increase the lift and they can therefore be used to increase the angle of glide in an approach to a landing. They do not, however, give satisfactory and instantaneous control of the flight-path angle because the use of the flaps ordinarily involves a change of speed, and therefore of kinetic energy, that tends to give a momentary action in the opposite direction to that desired. For example, as the flap is extended to increase the steepness of descent the lift increases and the airplane ordinarily attains a new balance at a lower speed. The kinetic energy associated with the speed loss is dissipated by lifting the airplane from its original flight path, and it travels a matter of several hundred feet before the actual flight path crosses the projection of the original path and the glide is changed in the desired manner. Conversely, if the airplane is gliding steeply at low speed with the flap extended and an attempt is made to flatten by retracting or neutralizing the flap, the lift is reduced and the speed increases until a new condition of balance is reached; the airplane in this case drops below the projection of its original flight path until it has traveled a distance of several hundred feet. Thus the flaps are not in themselves suitable to give direct control of the gliding angle but are merely useful (in addition, of course, to giving a reduction in the minimum speed available) in converting a medium or low-drag airplane into one having a higher drag and consequently a steeper glide.

The purpose of the present investigation was to find, if possible, a flap arrangement suitable for direct and immediate control of the glide-path angle. In this connection, it was considered desirable that the approach to a landing consist of a glide at low speed with a wide range of flight-path angles available. It was assumed that the speed of approach should be a sufficient amount above the minimum speed to give a reserve for countering the effects of gusts and for flaring off the glide path at contact and that the airplane should be so arranged as to balance at this speed with all flap settings used in the approach and landing maneuver. A study of the results of other flap tests indicated that the best results would very likely be obtained by means of a slotted flap arranged to have a high lift with a low deflection, say 20° or 25°, and consequently a relatively low drag, if slot proportions could be found that would give about the same maximum lift with further flap deflection to a high angle with its accompanying high drag. A number of preliminary tests were therefore made in an attempt to find a reasonably satisfactory arrangement of this nature. Some of the most significant results are given in the present paper.

APPARATUS AND METHODS

A cross section of the airfoil with flap is shown in figure 1. In order that the flap itself might attain as high a lift as possible with a relatively low deflection the flap portion of the wing was formed to an airfoil section (Clark Y). Two main forms of slot were used, the difference being in the shape of the lower surface of the airfoil just ahead of the flap. Slot 5D was formed with a sharp corner similar to the type that the tests of reference 1 indicated would have a low drag. Slot 6 had the corner removed and the under surface faired into a gentle curve, a form that seemed promising. With both forms of slot, tests were made with the flap located in several positions with respect to the main portion of the wing, giving further changes in the slots with flap deflection.

The 7- by 10-foot wind tunnel, which is of the open-jet type, is described in reference 2. For the present tests, the model airfoil was supported on the regular balance but was located between two large vertical plates extending entirely through the air stream from top to bottom and spaced 20 inches apart. Thus, the air flow over the model was essentially two-dimensional in character. This apparatus is described in reference 3. The results are not corrected for the deflection of the tunnel air stream.

RESULTS AND DISCUSSION

The first tests were made with slot 5D, the flap hinge axis being tried in several different locations with respect to the wing and the flaps being tested at various deflection angles. The positions and deflections were chosen to cover with the minimum number of tests the conditions that seemed likely to give high lift with low deflection and to maintain the high lift as the deflection was increased. The results have been plotted in two different ways: first, as charts showing the variations of maximum lift with flap position for a given deflection (fig. 2); and second, as a series of polar curves for the different flap deflections with one axis location (figs. 3 to 6). Position O1 (fig. 3) was the only one that gave reasonably satisfactory results. For this position, the maximum lift coefficients were very nearly constant at approximately 1.90 for all flap deflections from 30° to 80° and by interpolation it would seem that this would probably hold true down to 25°. The value for a deflection of 20° was only slightly lower, being 1.83. At a constant value of the lift coefficient suitable for the glide approach to a landing, say a value of 1.4, the drag increased quite regularly with increase in flap deflection above 20°, indicating that if the airplane were balanced so as to maintain a speed corresponding to such a constant lift coefficient and if the flap control forces were reasonably low and regular, the flap would provide a satisfactory glide-angle control. The drag at a lift coefficient of 1.4 increased greatly with increased flap angle, its value with the 80° deflection being more than double that with the 20° deflection.

It is of interest in this connection that the angle of attack, as shown by the light dashed lines of figure 3, remains practically constant for a given value of the lift coefficient for all flap settings between 30° and 80°. The pitching-moment coefficients with this slot and flap arrangement, as shown in figure 7, are practically the same for flap deflections from 30° to 60° and are not greatly different for the 20° and 80° deflections, indicating that there should be no great difficulty in providing that an airplane maintain balance at an approximately constant speed throughout a large range of flap deflections. The absolute values of the pitching moments obtained with the present test arrangement do not agree exactly with those obtained for similar airfoils of aspect ratio 6, but the differences in moment with different flap settings are reasonably accurate.

The results for the wing with slot 6 are given in figures 8 to 12. The results are not greatly different from those obtained with slot 5D, positions A'1 and 01 both being fairly satisfactory. As shown by the contour lines of figures 2 and 8, the exact location of the flap is somewhat less critical with slot 6 than with slot 5D, high values of the lift coefficient being obtained throughout a larger range of positions. The maximum lift coefficients obtained with the different deflections were not quite so uniform, however, as those obtained with slot 5D, position 01. With slot 6 the 40° deflection gave a slightly lower value than the other deflections tested, and with position 01 the 30° deflection gave a higher value than the others.

The lowest drags for the conditions representing high speed and gliding flight were obtained with the flap set at -5°. The same value of the minimum drag coefficient was found with both forms of slot.

The position of the hinge axis on the flap that was used in the present tests, and the resultant aerodynamic balance of the hinge moments, was arbitrarily chosen to enable comparison with preliminary unreported tests made with a different flap. If a different amount of balance is desired, an approximate idea of the lift coefficients available can be obtained for the new position of the flap with its various deflections from the values given in figures 2 and 8.

The results of these more or less qualitative preliminary tests indicate the desirability of attempting the use of flaps of this nature for controlling the glide path of an airplane in flight and, if the flight tests show this form of control to be desirable, of making a more complete wind-tunnel investigation.

CONCLUSIONS

1. A slotted flap arrangement was found that gave a reasonably high maximum lift coefficient and a relatively low drag with a low flap deflection and that maintained this lift coefficient with a regular increase in the drag coefficient as the flap deflection was increased up to 80°.

2. Only minor differences were found in the aerodynamic characteristics of the wing with the two general forms of slot tested.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., August 8, 1935.

REFERENCES

1. Weick, Fred E., and Wenzinger, Carl J.: The Characteristics of a Clark Y Wing Model Equipped with Several Forms of Low-Drag Fixed Slots. T.R. No. 407, N.A.C.A., 1932.

2. Harris, Thomas A.: The 7 by 10 Foot Wind Tunnel of the National Advisory Committee for Aeronautics. T.R. No. 412, N.A.C.A., 1931.

3. Wenzinger, Carl J.: Wind-Tunnel Investigation of the Aerodynamic Balancing of Upper-Surface Ailerons and Split Flaps. T.R. No. 549, N.A.C.A., 1935.

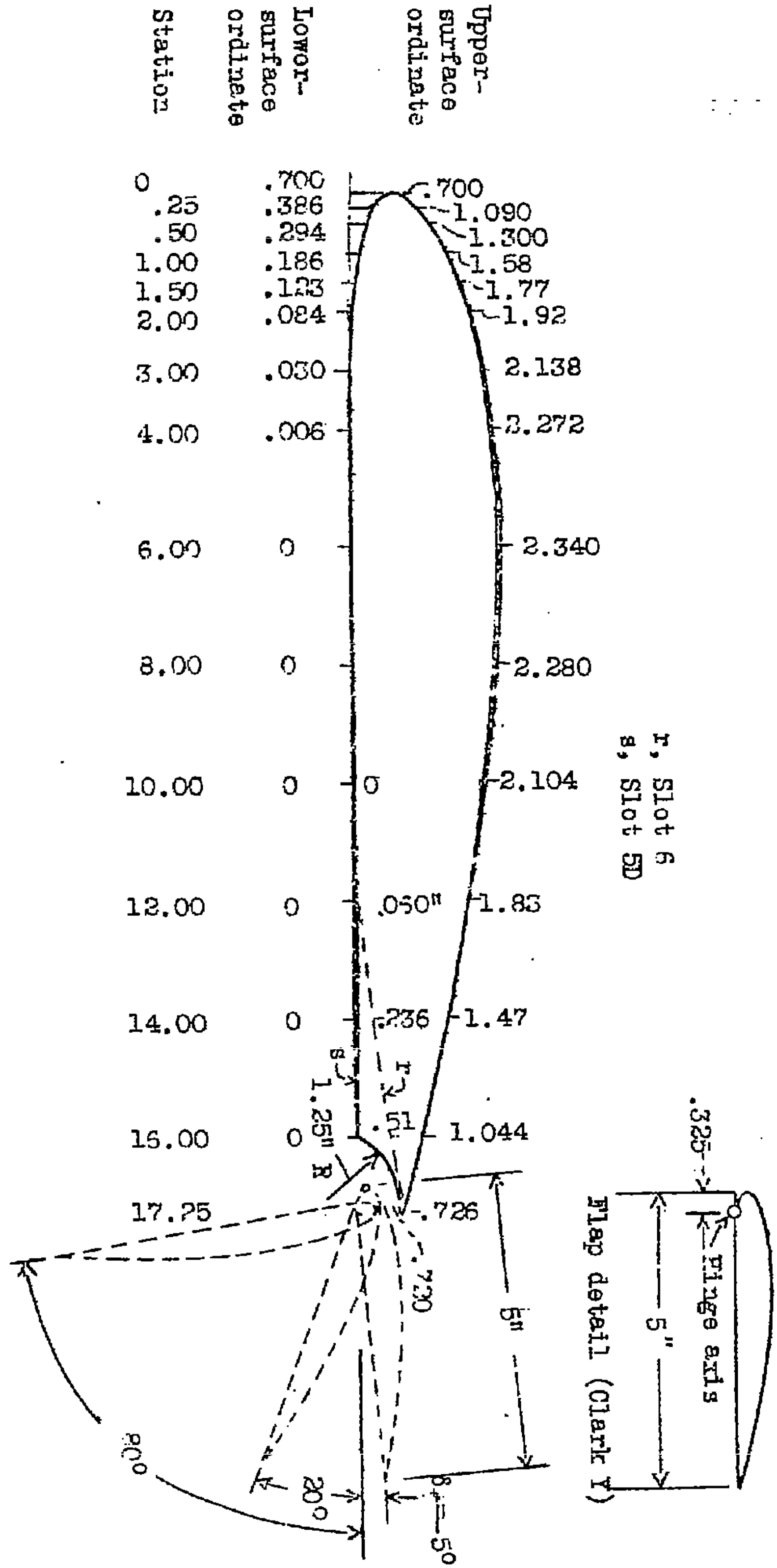

Figure 1.-Details of airfoil sections and flap. (Dimensions in inches).

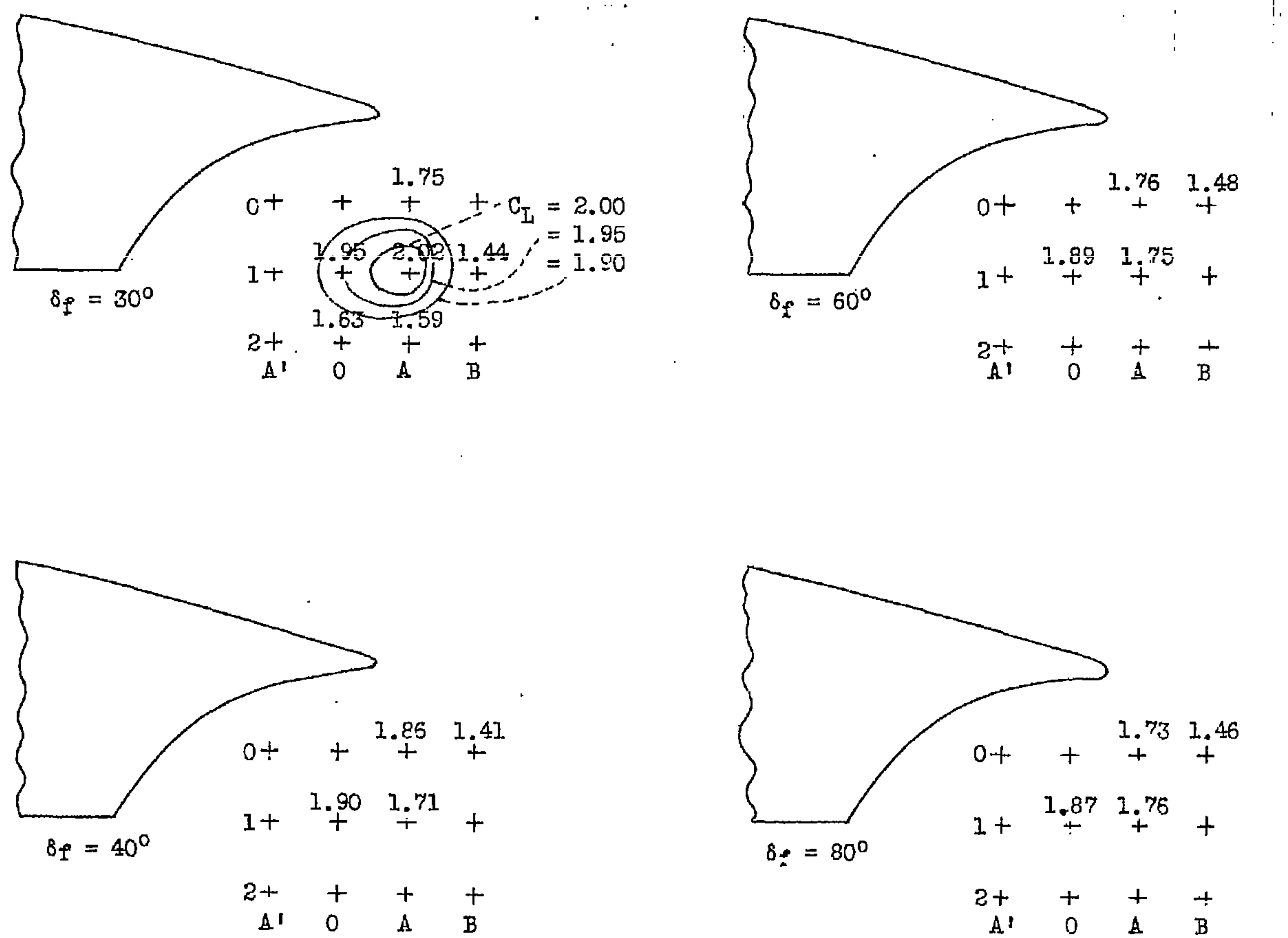

Figure 2.- $C_{L_{max}}$ against flap hinge axis location for flap deflections of 30°,40°,60°,and 80°. Slot 5D.

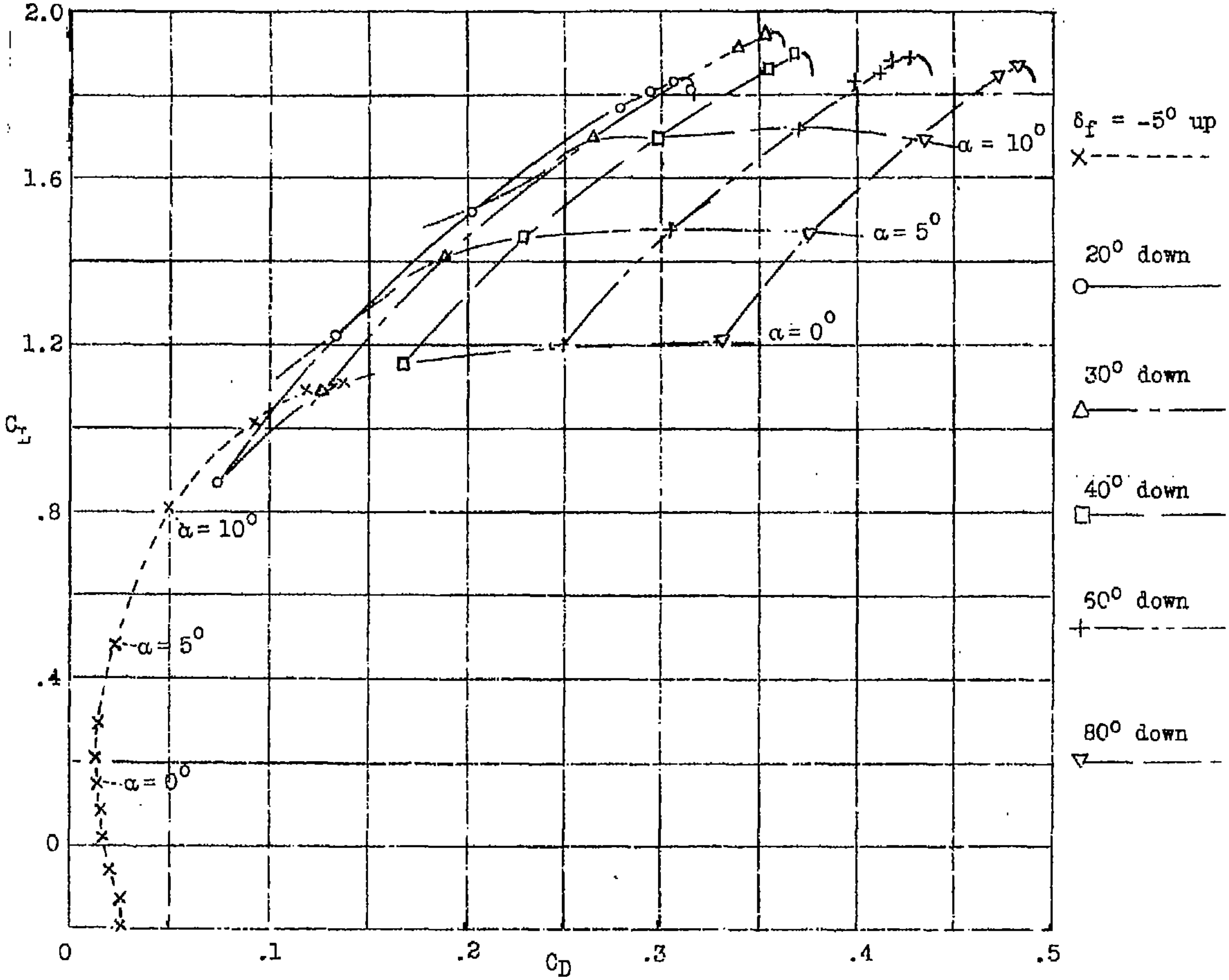

Figure 3.- Polar curves for wing with flap at position 0 1. Slot 5 D.

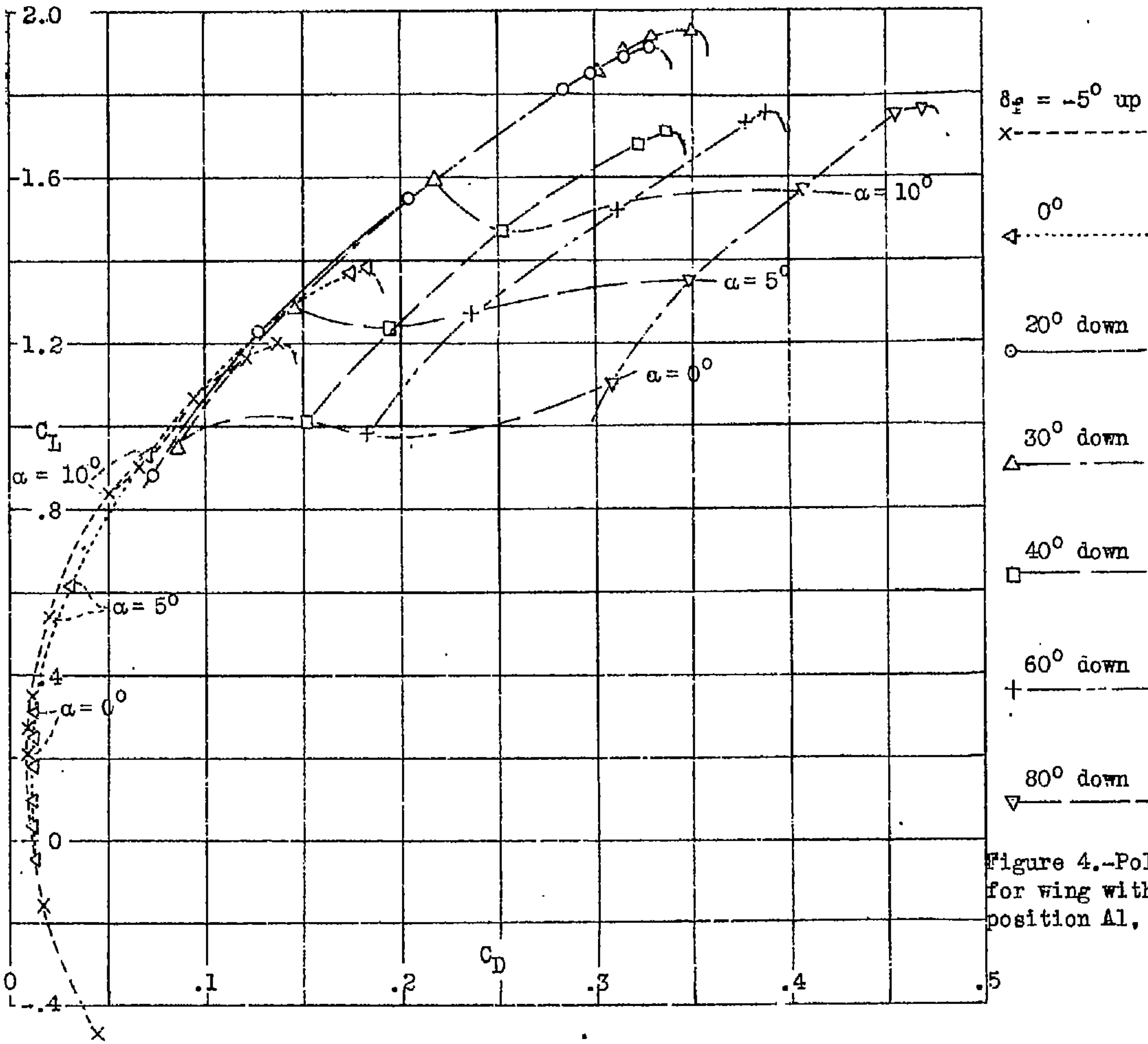

Figure 4.-Polar curves for wing with flap at position A1, Slot 5D.

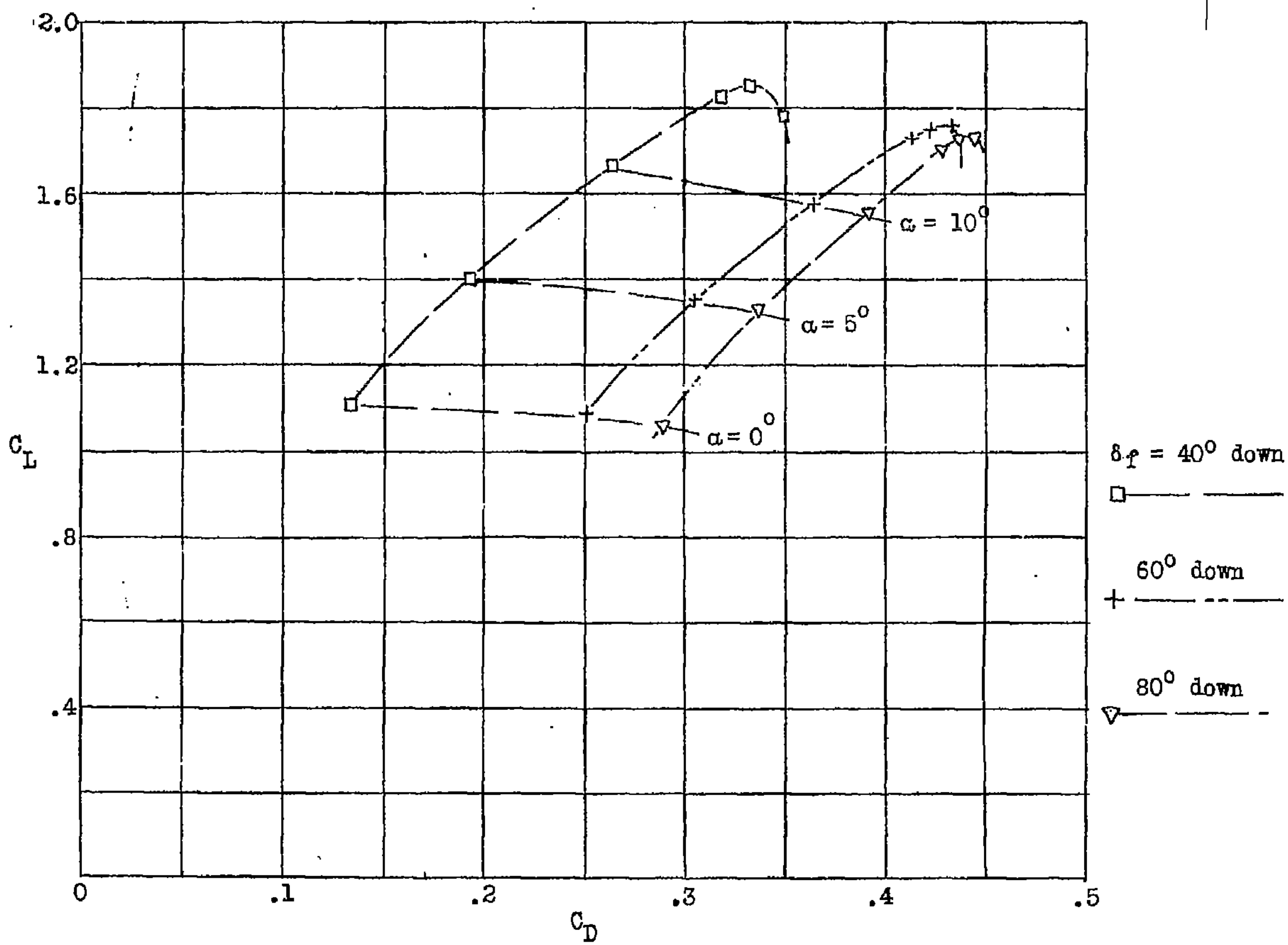

Figure 5.-Polar curves for wing with flap at position A0. Slot 5D.

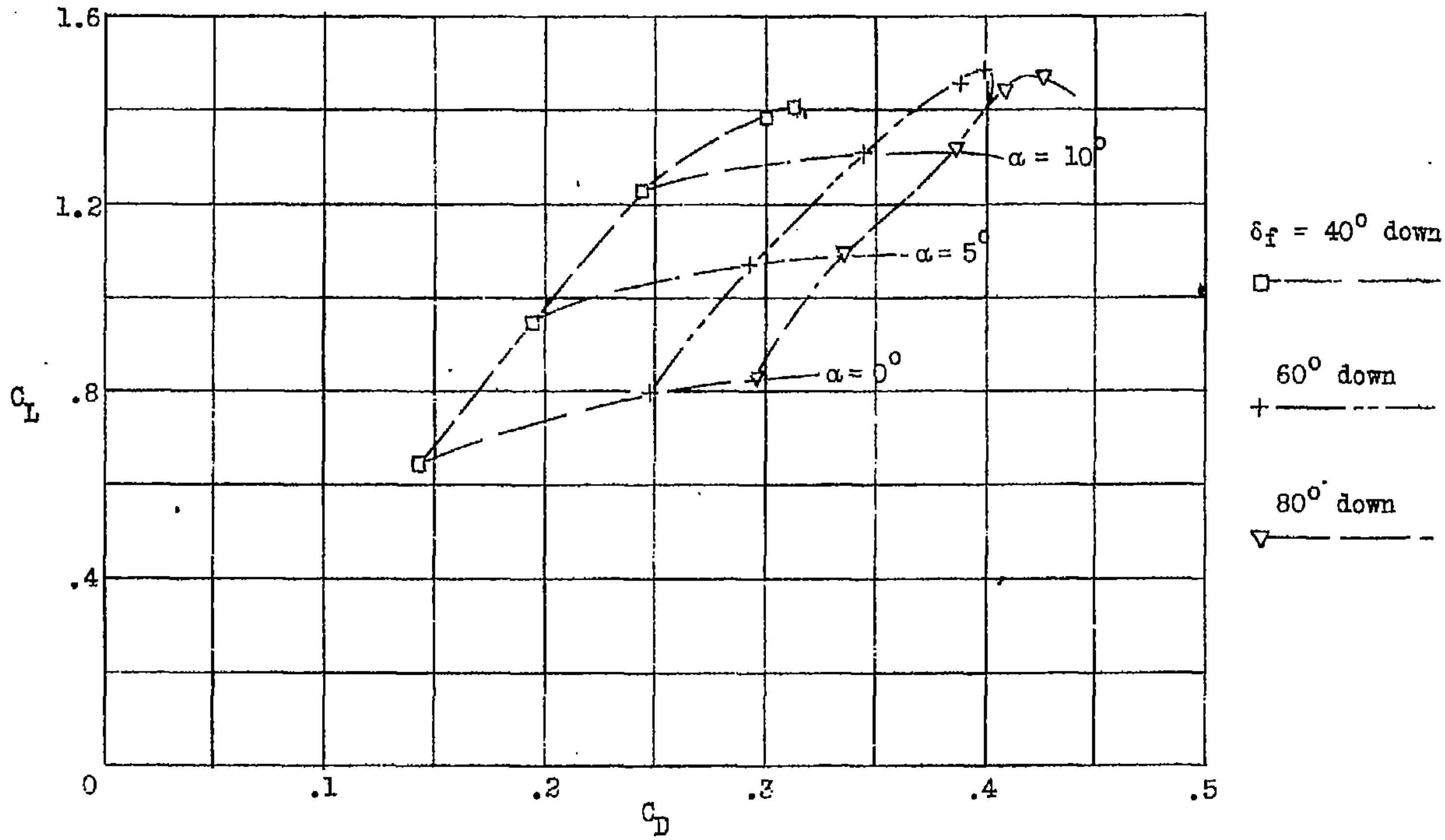

Figure 6.-Polar curves for wing with flap at position E0. Slot 5D.

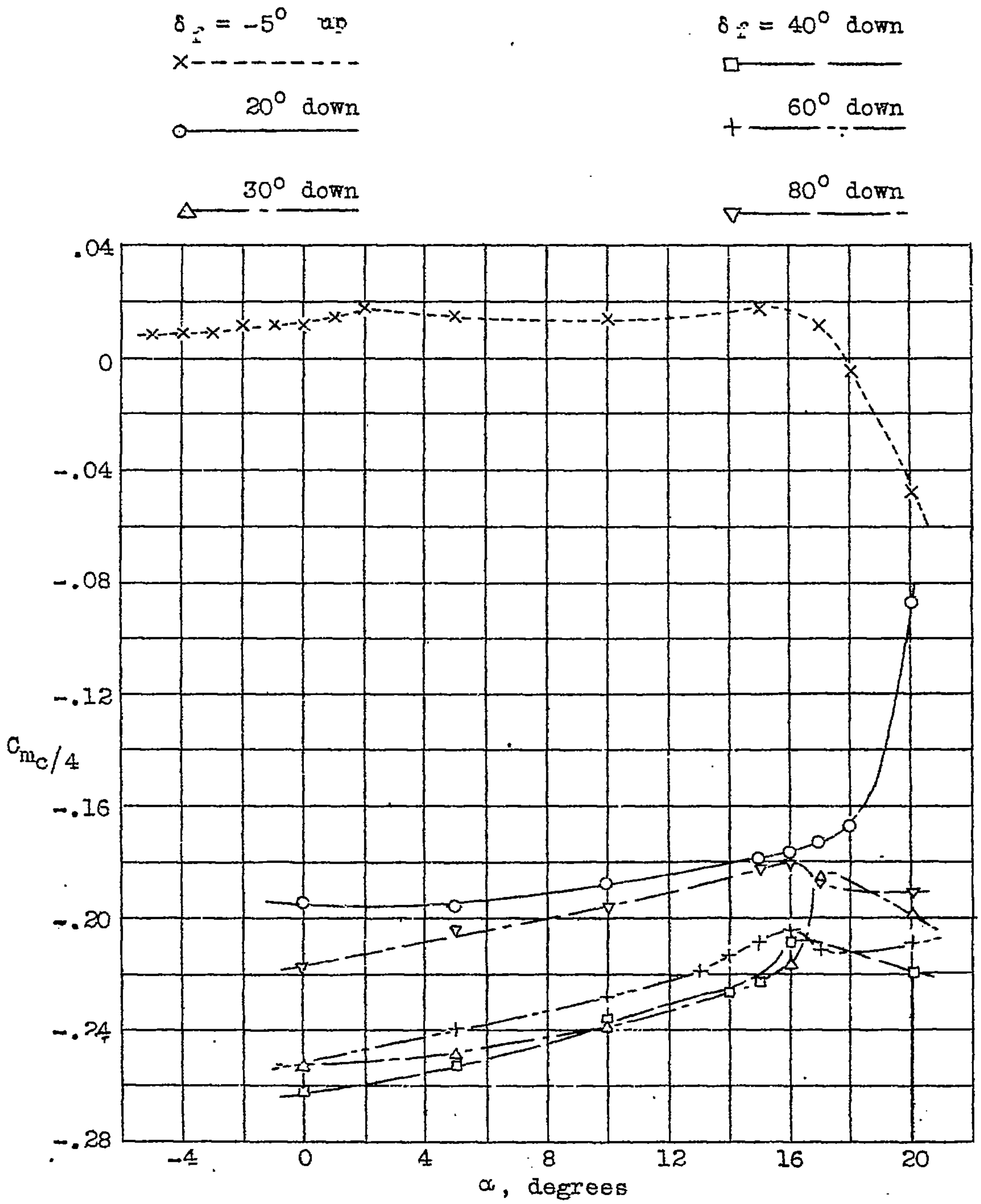

Figure 7.-Pitching-moment coefficient for wing with flap at position 01. Slot 5D.

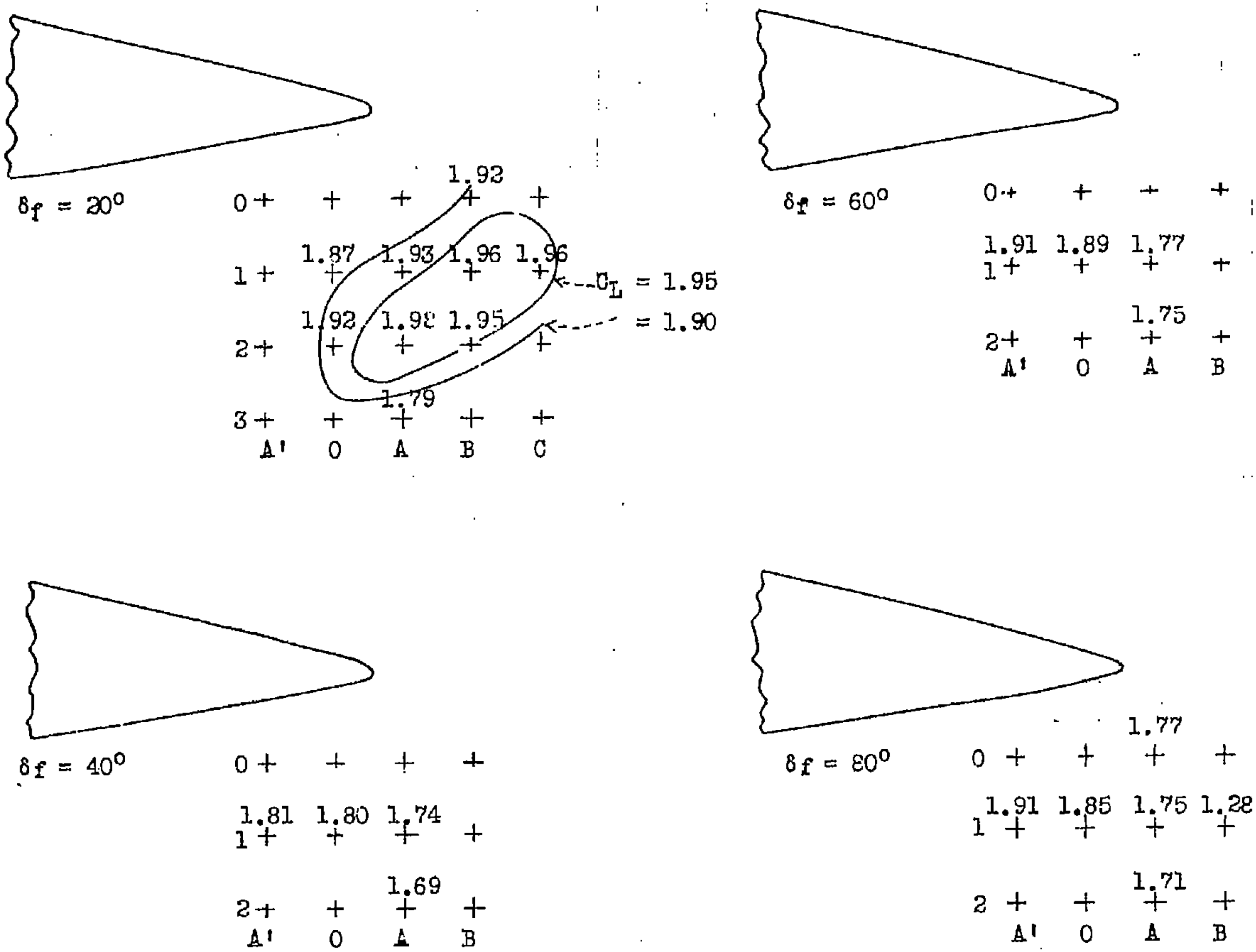

Figure 8.- $C_{L_{max}}$ against flap hinge axis location for flap deflections of 20°,40°,60°,and 80°. Slot 6.

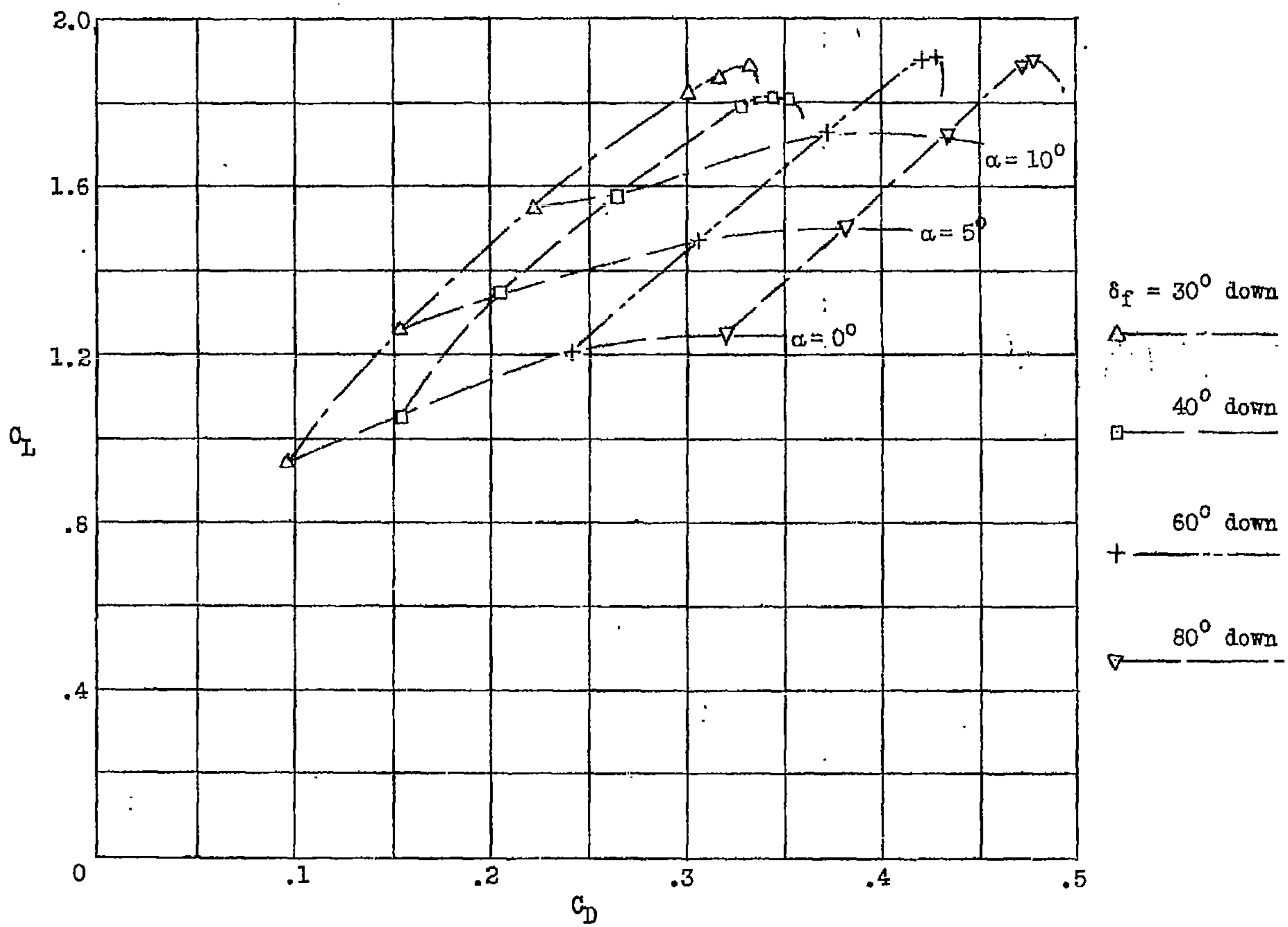

Figure 9.-Polar curves for wing with flap at position A'1. Slot 6.

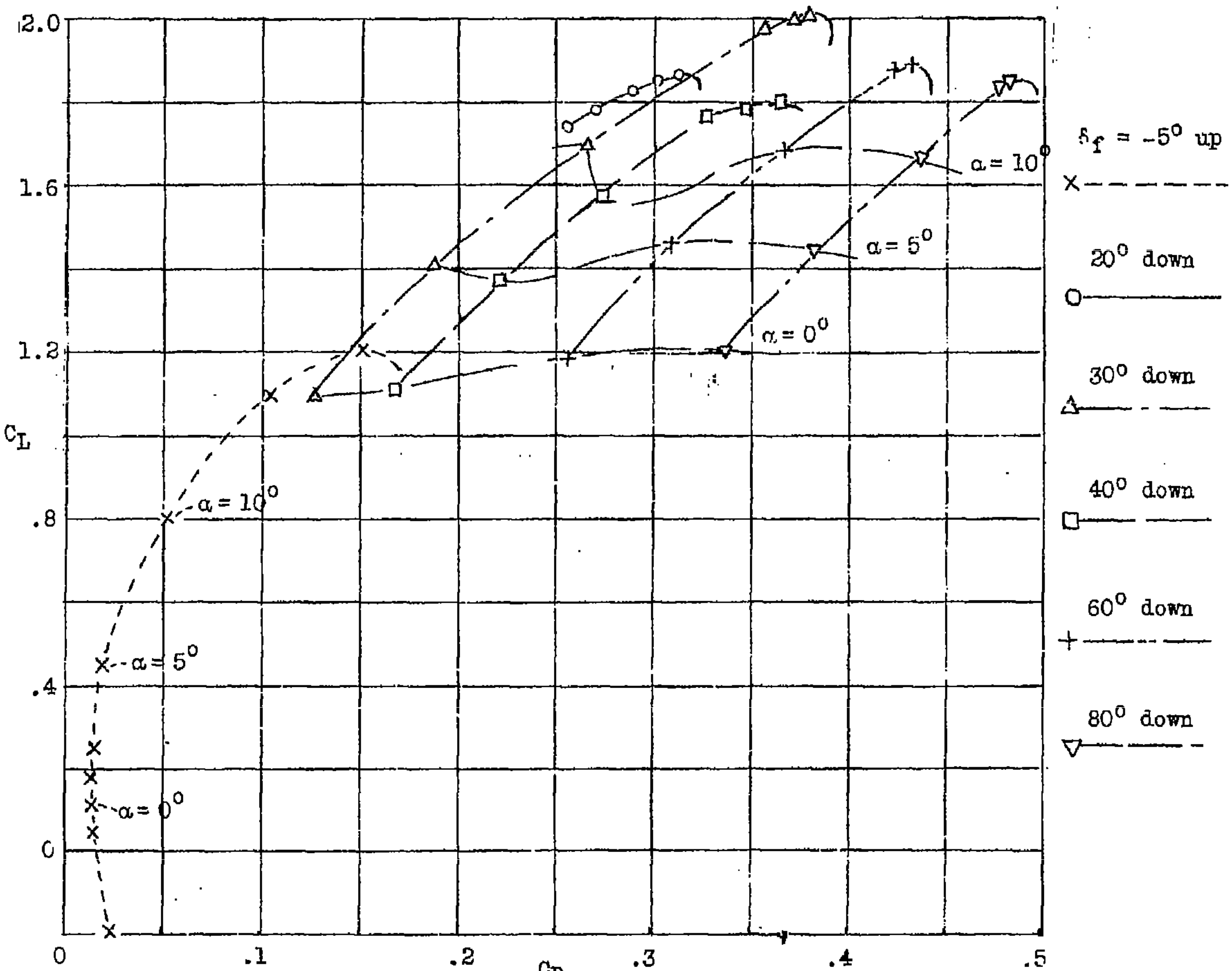

Figure 10.- Polar curves for wing with flap at position 0 1. Slot 6.

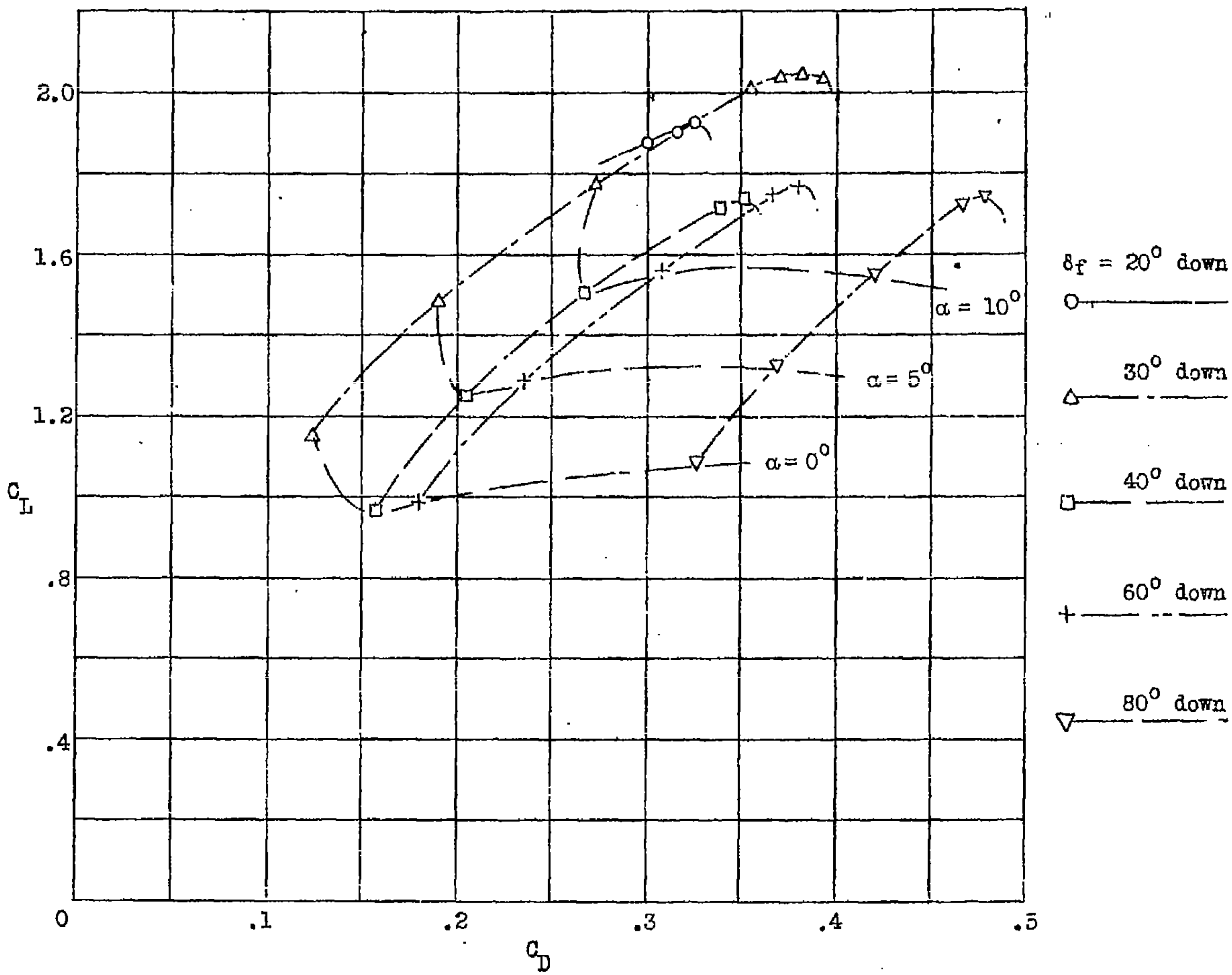

Figure 11.-Polar curves for wing with flap at position A1. Slot 6.

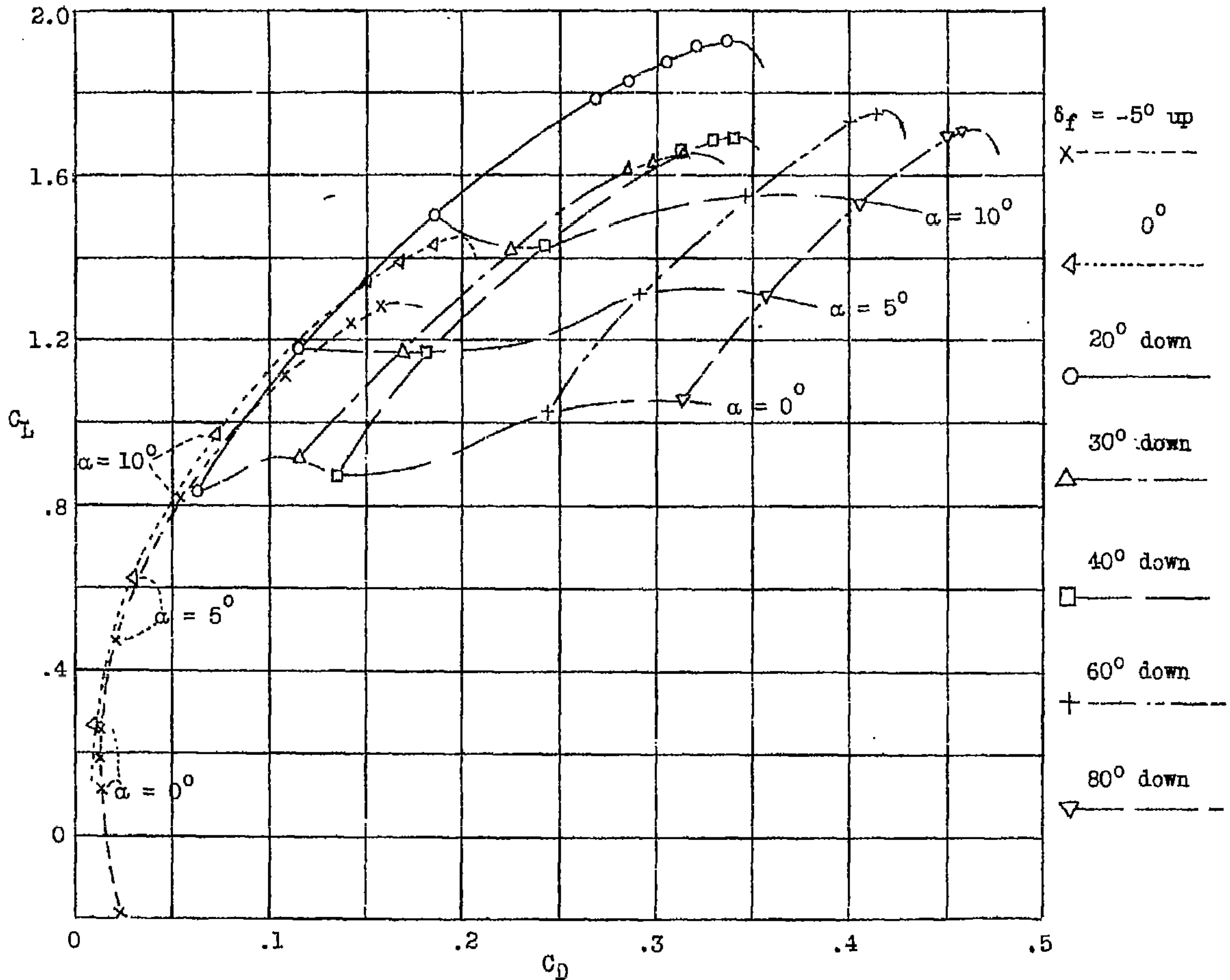

Figure 12.- Polar curves for wing with flap at position A 2. Slot 6.